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MEDICAL RESEARCH DEPARTMENT

U.S. Submarine Base
New London

COMPARISON AND EVALUATION OF AMERICAN OPTICAL CO. PSEUDO-ISOCHROMATIC PLATES FIRST AND SECOND EDITIONS

First and Final Report
on
BuMed X-480 (Av-255-p)

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COMPARISON AND EVALUATION OF AMERICAN OPTICAL CO. PSEUDO-ISOCHROMATIC PLATES FIRST AND SECOND EDITIONS

Work was conducted under
Bulled X-480 (Av-255-p)
Entitled "Comparison and Evaluation of the 'Pseudo-Isochromatic Plates for testing of Color Perception' American Optical Company, Second Edition, with the First Edition of these plates now in general use by the U.S. Navy"

Subject research project was performed by
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Research Dept. of this activity.

This report is a first and final report under this project

16 July 1945

Medical Research Department
U. S. Submarine Base, New London, Connecticut

COMPARISON AND EVALUATION OF
AMERICAN OPTICAL CO. PSEUDO-ISOCHROMATIC PLATES
FIRST AND SECOND EDITIONS

The first and second editions of the American Optical Company's "Pseudo-Isochromatic Plates for Testing Color Perception" were administered to 200 men at the Amphibious Training Command, Naval Operating Base, Norfolk, Virginia. Seven individuals failed to meet the present standards of color perception by use of the first edition and 45 would have been disqualified according to the tentative standard established for the second edition.

The data are analyzed and recommendations designed to make the second edition more accurate and easy to administer are made.

INTRODUCTION

A second edition of the American Optical Company's "Pseudo-Isochromatic Plates for Testing Color Perception" has been prepared. Among the changes made in this edition are the placing of two demonstration plates at the beginning followed by thirty-six testing plates each mounted on a single page and arranged in nine groups containing four plates each.

The purpose of this paper is to present the results of a comparison and evaluation of the second edition, with the first edition of these plates now in general use by the U. S. Navy. Answers were sought to the following questions:

1. Do personnel showing hesitancy or difficulty with the old tests show similar hesitancy with the new test?
2. Are known color-weak persons detected?
3. Are these new tests harder to memorize?
4. Is the new edition easier or harder to administer?

PROCEDURE

Two hundred individuals at the Amphibious Training Command, Naval Operating Base, Norfolk, Virginia, served as subjects. The group was composed of 70 officers and 130 enlisted men. All were selected at random, and each was examined privately and uniformly by the principal investigator.

The directions accompanying the second edition specify that "Illumination should be either clear daylight or by means of artificial white light". In order to test the effect of illumination, individuals were divided arbitrarily into two equal groups. The first group of one hundred subjects was examined under a Daylight Fluorescent lamp (Dazar type). The second group of one hundred was examined under north daylight illumination.

All of the test plates were displayed at a distance of two to three feet from the eyes of the subjects, who were directed to read them within three to four seconds. Each man was also instructed to attempt to follow the same rate of speed in scanning each edition. In order to determine the amount of hesitancy encountered, measurement was made of the time required for each of 156 individuals to read each set of plates.

In every instance the complete set of plates in the first edition was shown, followed at once by the complete set of plates in the second edition, and the responses were recorded. This procedure was not modified, since it was soon discovered that the arrangement and order of plates of the two editions were varied sufficiently to avoid boredom of subjects and apparently obviate the learning factor.

RESULTS

The total number of errors for each of the thirty-six plates in the second edition, made by two hundred men, are presented in Figure 1. One plate, No. 28, was miscalled by 156 subjects. 24 of the plates were read incorrectly by less than 20 persons. It is evident that some plates presented far greater difficulty than others for the 200 men tested, and that the second edition does not spread the errors evenly among groups of plates.

Individual Scores

Tentative standards for the second edition are as follows:

(a) Enlisted personnel: read correctly not less than two (2) plates of each color group.
(b) Commissioned or warrant officer personnel, including nurses, candidates for the U. S. Naval Academy, and candidates for Naval Aviation or Aviation Pilot: read correctly not less than three (3) plates of each color group.

Table 1 lists the subjects who failed to meet these standards.

FIGURE 1

TOTAL NUMBER ERRORS FOR EACH PLATE

N = 200

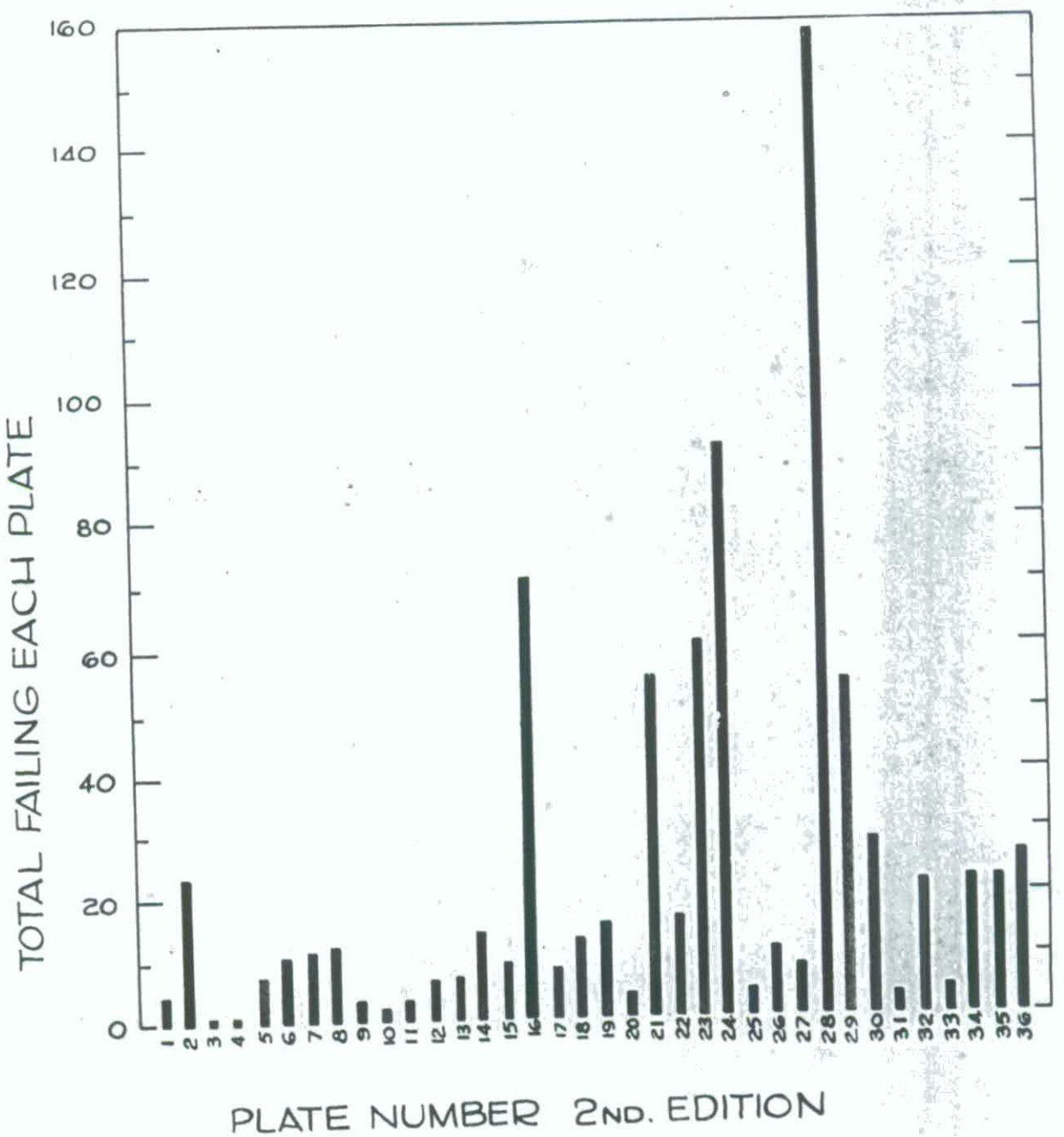


TABLE ONE
SUBJECTS WHO FAILED A. O. PSEUDO-ISOCHROMATIC
PLATES SECOND EDITION

Subject No.	Rank or Rate	No. Plates Failed Second Edition	First Edition	Group No. 1	2	3	4	5	6	7	8	9
41	Lieut.	33	41	1	2	3	4	5	6	7	8	9
12	Lieut.	32	37		2	3	4	5	6	7	8	9
44	Lieut.	29	29		2	3	4	5	6	7	8	9
11	Lt.Col(RE)	27	30		2	3	4	5	6	7	8	9
180	PhM3c	25	14		2		4	5	6	7	8	9
192	CRM	25	14		2		4	5	6	7	8	9
122	PhM2c	20	15		2			5	6		8	9
101	S2c	17	17		2				6		8	
116	(Enl)	16	14		2		4	5				
107	S1c	10	2						6			
110	PhM2c	10	3									9
128	St2c	10	4						6			
58	CSC	9	6				4		6		8	
81	Ensign	9	0						6			9
151	S2c	9	9						6			
17	Lieut.	8	4						6		8	
114	Lieut.	8	2						6		8	
153	HAlc	7	5						6			
158	HAlc	7	1						6			
199	HAlc	7	4									9
10	Lt.Comdr.	6	0						6			
164	Comdr.	6	1						6	7		
174	Lieut.	5	2									9
39	HAlc	5	1						6			
49	Lieut.	5	0						6			
56	Y2c	5	4						6			
57	Ensign	5	2								8	
167	Comdr.	4	2									9
8	Lt.(jg)	4	0									9
48	Ensign	4	1									9
72	Y3c	4	0						6			
74	Lt.Comdr.	4	0						6			
77	Lieut.	4	1									9
80	Ensign.	4	0									9
139	Lieut.	4	1								8	
19	C.Pharm.	4	1						6			
165	Comdr.	3	0									9
4	Lt.Comdr.	3	0						6			
21	Lt.Comdr.	3	3									9
35	Lt.(jg)	3	2						6			
45	Lieut.	3	4						6			
60	Comdr.	3	0						6			
183	Lieut.	3	0									9
1	Lieut.	2	0						6			
26	Ensign	2	1									9
Total No. Subjects Failed = 45				1	9	4	8	8	30	7	13	20

From Table 1 it is apparent that 45 individuals failed to meet the prescribed standards. It is worthy of note that only personnel with the highest incidence of errors failed groups two (2) and five (5). Only one individual failed group one (1), and the subjects missed groups six (6) and nine (9) with the greatest frecuency.

Comparison of First and Second Editions

It is interesting to note from Table 1 that both editions select the same 9 individuals who have greatest difficulty in reading the plates correctly. At this point the present standards prescribed for the first edition may be stated(1).

(a) Applicants for enlistment in the Navy and Naval Reserve except in classes V-1, V-5, and V-7: correctly recognize only one plate in each of the three color groups, represented by plates 1, 2, 3, 4 (numbers 89, 43, 56, 27), by plates 7, 8, 9, 10, 13, 14 (numbers 39, 42, 56, 27, 66, 75), and by plates 17, 18, 19, 20 (numbers 25, 68, 97, 34).

(b) Applicants for commission, for duties involving flying and for classes V-1, V-5, and V-7 must read all plates correctly, but the following interpretation shall be accepted as satisfactory:

Plate	Acceptable Response
2	43 or 48
7	39 or 89
14	75 or 76
22	34 or 84
28	43 or 48
30	75 or 25
33	No number or 45
34	No number or 73
38	394 or 894

(1) Bureau of Medicine and Surgery Circular Letter P2-5/P3-1 (103); AM/brf; September 25, 1942. "Proper Interpretation of Navy Color Vision Tests."

FIGURE 2

DISTRIBUTION OF ERRORS — 2ND EDITION

N = 200

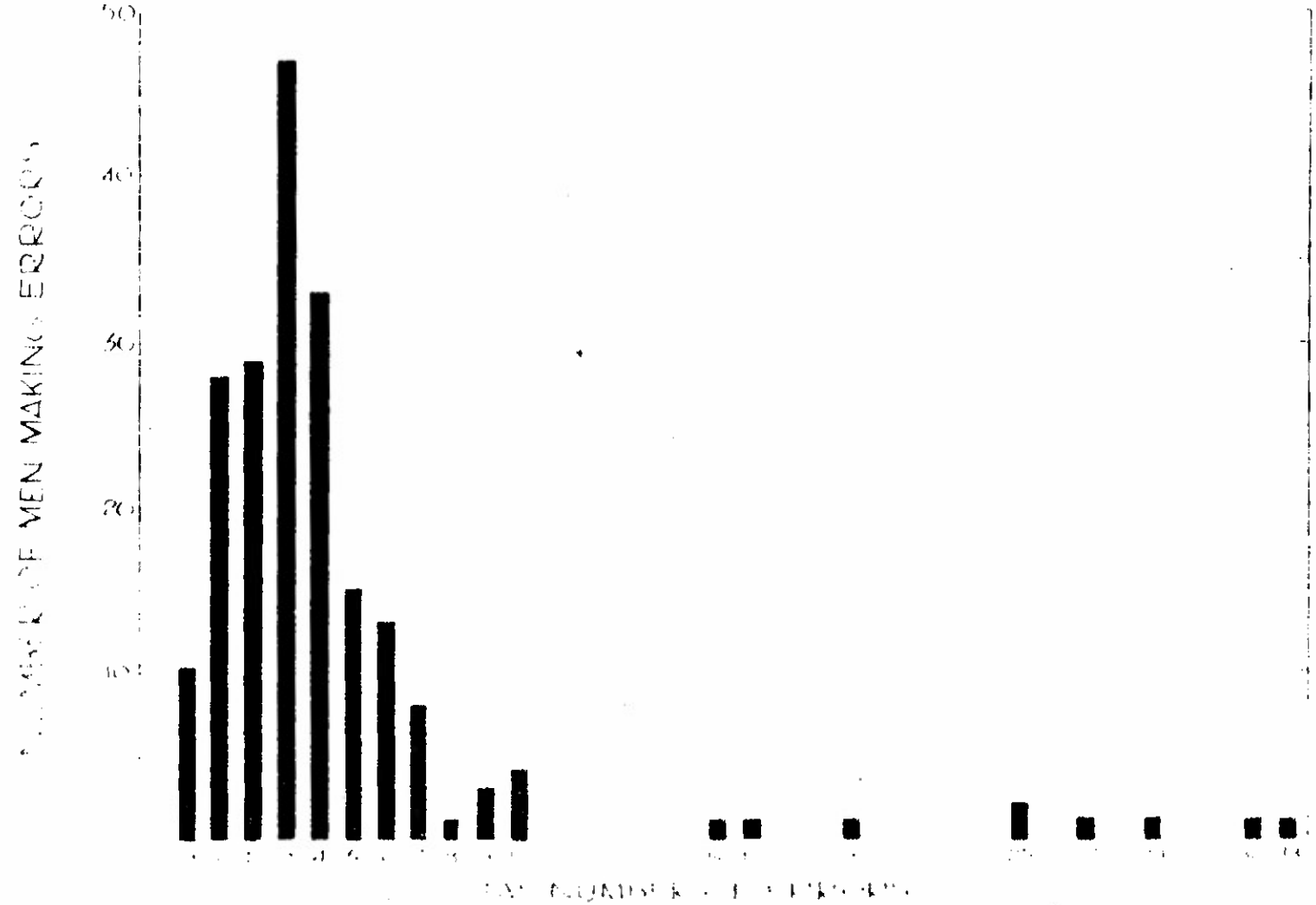


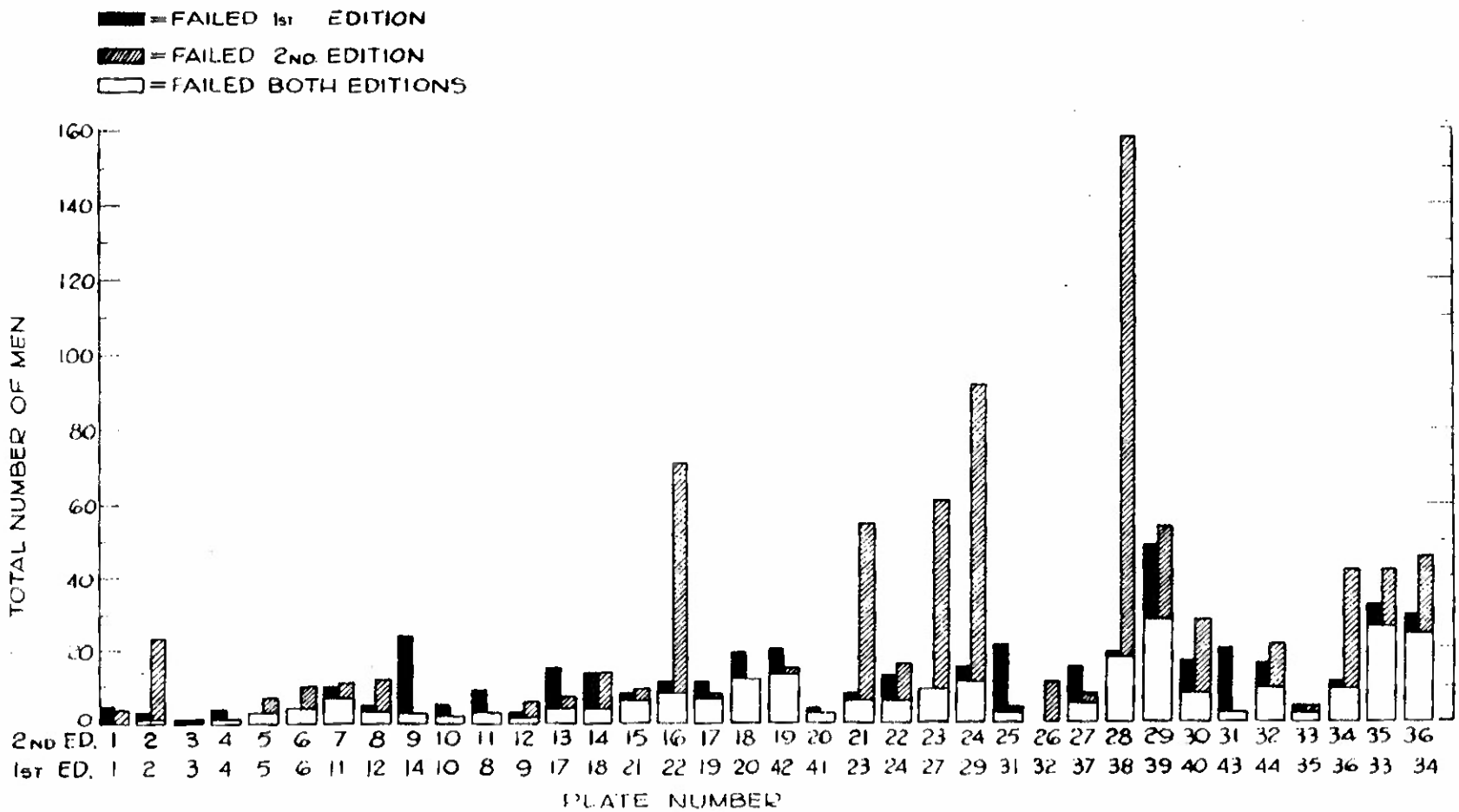
TABLE TWO

CORRESPONDING PLATES OF FIRST AND SECOND EDITION
COMPARED FOR RELATIVE DIFFICULTY

Corresponding Plate Numbers		Number of Failures Per Plate		Number of Failures For Corresponding Plates Both Editions
Second Edition	First Edition	Second Edition	First Edition	
1	1	4	5	0
2	2	23	3	1
3	3	1	1	0
4	4	1	4	1
5	5	7	3	3
6	6	10	4	4
7	11	11	10	7
8	12	12	5	4
9	14	3	24	3
10	10	2	5	2
11	8	3	9	3
12	9	6	3	2
13	17	7	15	4
14	18	14	14	4
15	21	9	8	6
16	22	71	11	8
17	19	8	11	7
18	20	12	19	12
19	42	15	20	13
20	41	3	-	3
21	23	55	8	6
22	24	16	13	6
23	27	61	9	9
24	29	92	45	11
25	31	4	21	3
26	32	11	0	0
27	37	8	13	5
28	38	158	19	18
29	39	54	41	28
30	40	28	17	8
31	43	3	10	3
32	44	21	16	9
33	35	4	4	3
34	36	42	21	9
35	33	42	32	26
36	34	46	29	24

FIGURE 3

CORRESPONDING PLATES OF 1ST. AND 2ND. EDITIONS COMPARED FOR RELATIVE DIFFICULTY



Hesitancy in Reading

In a further consideration of the two editions with respect to their comparative difficulty, the interval of time required for 168 subjects to scan each edition is shown in Table 3.

Table Three

Comparison of Hesitancy for Each Edition

Required longer time for first edition (46 plates)	110
" " " " second " (36 plates)	78
Total	188

Relative Ease of Memorization

Some individuals were interrogated for their subjective impressions of the relative difficulty in the memorization of each of the two editions; the opinions of 83 men are shown in Table 4.

Table Four

Considered first edition more difficult to memorize	39
" second " " " " "	44
Total	83

Ease of Administration

Seven Medical Officers who took the test were questioned regarding the relative ease of administration of the two editions. The results are shown in Table 5.

Table Five

Number of Medical Officers considering first edition easier to administer	1
Number of Medical Officers considering second edition easier to administer	6
Total	7

TABLE SIX

EFFECT OF ILLUMINATION
IN CASES MAKING INCORRECT RESPONSE

Second Edition Plate Number	No. Errors Under Artificial Daylight	No. Errors Under Daylight	Total No. Errors
1	2	2	4
2	8	15	23
3	1	0	1
4	0	1	1
5	4	3	7
6	5	5	10
7	5	6	11
8	5	7	12
9	3	0	3
10	2	0	2
11	3	0	3
12	4	2	6
13	5	2	7
14	8	6	14
15	4	5	9
16	35	36	71
17	4	4	8
18	5	7	12
19	7	8	15
20	3	0	3
21	27	28	55
22	10	6	16
23	27	34	61
24	43	49	92
25	3	1	4
26	7	4	11
27	6	2	8
28	74	84	158
29	25	29	54
30	11	17	28
31	3	0	3
32	9	12	21
33	3	1	4
34	10	32	42
35	15	27	42
36	17	29	46
Totals	403	464	867
Average	11.2	12.9	24.1

DISCUSSION

From the results of the present experiment, in which two editions of the American Optical Company's plates were used, certain observations may be made.

The Pseudo-Isochromatic Type of Test

The two editions of the American Optical Company's Pseudo-Isochromatic Plates are designed to detect normal and weak color perception. That this objective is not achieved fully by the first edition is suggested by a report (2) which states that "The A. O. test as generally administered and interpreted in the Navy, is concluded to be unreliable and largely inefficient as a test for color vision".

In the opinion of the writer, some desirable attributes for a pseudo-isochromatic test for color vision are:

(1) Selective, relatively brief, and easy to administer.
(2) Composed of test-characters least liable to be confusing.
(3) Arranged in some order of difficulty.
(4) Capable of interpretation in order to indicate some type of classification of color defects.

With the foregoing points in mind, the data from the experiment are considered.

Responses to Pseudo-Isochromatic Plates

A study of the raw data shows that when the A. O. Pseudo-Isochromatic color test is administered to a group of individuals, four types of responses are encountered. These are:

(2) "A Study of Methods Used in Administering Pseudo-Isochromatic Test Plates for Color Vision". (Color Vision Report No. 3, Medical Research Laboratory, U. S. Submarine Base, New London, Conn., 1943.)

(1) A statement that no number or pattern can be identified.
(2) An incorrect number interpreted.
(3) Plates with alternative readings interpreted in either of the two possible ways, or a combination of these.
(4) Plates interpreted correctly.

Reference to the data presented in Figure One would appear to indicate that certain plates of the second edition elicit more incorrect responses than others. Table 6A summarizes the plates of the second edition on which the highest incidence of errors was made. In this respect plate No. 28 is outstanding. While it was miscalled by 158 subjects who made 16 different types of response, a plate of closely similar type, No. 27, was miscalled by only 8 subjects. (Not listed in Table 6A)

Table 6A

Plates of Second Edition on Which Highest Incidence of Errors Was Made

Second Edition Plate No.	No. Men Making Incorrect or No Response	No. of Types of Incorrect Responses
28	158	16
24	92	21
16	71	6
23	61	13
21	56	10
29	54	9
36	46	8
35	42	5
34	42	1

From the results obtained by the other test-items of the second edition, and in view of the variety of responses to almost all of the above plates, it is probable that the nine plates listed in Table 6A are misinterpreted too frequently to be considered as of diagnostic value.

This view is reinforced by the fact that if the nine plates enumerated above were eliminated from the second edition, the result would be a more consistent group of scores (See Figure 1).

TEST-CRITERIA

The method of scoring the results of tests using the second edition, as quoted previously, permits an individual to miscall one or two plates in each group of four, for officer and enlisted personnel respectively. Hence a high incidence of errors for one plate in any group may not be a serious disadvantage of the second edition.

It is only when two or more plates in any one group are among those miscalled frequently, that difficulties arise in the detection of normal or weak color perception. Thus, when the nine groups of testing plates are considered in the light of data presented in Figure 1 and Table 1, it appears that groups six and nine are notable as being responsible for a relatively large number of failures. Because each of these two groups contain three of the plates which are miscalled frequently, they are missed by 42 of the 45 subjects who failed and include commissioned and enlisted personnel in a ratio of about 2 to 1. This incidence of 22.5% failing for the whole group of 200 subjects is excessive when compared with the results of other color vision studies of personnel of the U. S. Navy. Accordingly, it is felt that such a result is an unfavorable reflection on the tentative criteria prescribed for normal versus weak color perception, if the present test-items are unchanged.

This consideration leads to an evaluation of criteria of what constitutes normal color perception. It is a weakness of this experiment that one edition of pseudo-isochromatic plates is used in order to validate another edition of such plates. It is for this reason that Table 2 and Figure 3 have been formulated. In these presentations the performance on corresponding plates of the two editions are shown. Those plates which show the highest incidence of identical performance by individuals have been summarized in Table 7 below.

Table Seven

Plates With Highest Incidence of
Corresponding Individual Failures

Plate No. in Second Edition	Plate No. in First Edition	Total number of subjects whose failures correspond for 1st and 2nd editions.
29	39	28
35	33	26
36	34	24
28	38	18
19	42	13
18	20	12
24	29	11

Five of these seven plates of the second edition have been cited previously as being non-selective. It appears that plates of the first edition corresponding to these partake of the same faults. This process of elimination leaves plates #19 and #18 of the second edition and their approximate counterparts in the first edition, as being both comparable and selective.

The two plates in question were failed by 13 and 12 subjects respectively, which indicates on the sole basis of comparative performance in both editions, that either 13 or 12 subjects in the group of 200 are color deficient. On the basis of the standards set up for use with the first edition, seven subjects, all commissioned, fail to meet the requirements for color perception.

Reference to Table 1 shows that the 12 men who made the greatest number of errors failed 10 plates or more. This score gives a cut-off corresponding with the data presented in Figure 2, which appears to indicate a natural division at the level of about ten errors.

From the above considerations, a pass-fail criterion, on the basis of total number of plates miscalled in the second edition, is more indicative of normal or weak color perception then a criterion based on the number of groups of plates failed. The result of this modification of the criteria prescribed tentatively for the second edition would reduce the number of failures from 45 to a much lower number. Possible cut-off scores and the percentage of failures which would result from the data of the present experiment, are shown in Table 8.

Table Eight

Allowable No. of Errors	Resulting % of Failures
0	95.
1 - 2	66.5
3 - 4	26.5
5 - 6	12.5
7 - 9	6.5
10 - 14	4.5
15 - 19	3.5
20 or more	0

Considerations based on the preceding paragraph appear to suggest that to permit no subject, regardless of rank or rate, to make more than ten errors, would ensure that almost all color weak persons are detected, with a 4.5% rejection rate for a population composed of Navy personnel. The same requirement applied to the results of testing with the first edition would fail in the identification of exactly the same individuals (in the present experiment) as color weak.

TEST-ILLUMINATION

An examination of Table 6 suggests that more errors are made when subjects scan the second edition under daylight illumination. From this it might be concluded that daylight illumination is more selective than artificial daylight. Reexamination of this table shows that 17 plates are misinterpreted more frequently under daylight illumination. Nine of these have been discredited previously because they were not selective for deficient color perception. The remaining 8 plates which were miscalled more frequently under actual daylight illumination, are outweighed

numerically by 19 plates which were miscalled by artificial daylight illumination. From the foregoing it is considered that the latter type of illumination is probably more selective in the detection of weak color perception.

Conclusions:

From the result of the present experiment in which two editions of the American Optical Company's "Pseudo-Isochromatic Plates for Testing Color Perception" were administered to 200 individuals of the U. S. Navy, the following conclusions are drawn:

1. Personnel showing hesitancy or difficulty with the first edition showed hesitancy with the second edition.

2. Known color weak persons were detected by use of the second edition but some individuals were designated as color-weak who passed the requirements for color perception according to present Navy standards by the use of the first edition.

3. There are indications that the new test is probably more difficult to memorize.

4. Most of the medical officers consulted agree that the new edition is decidedly easier to administer.

5. The second edition shows a greater disparity than the first edition both in the number of failures among plates of the same group, and among the groups themselves.

6. Artificial daylight illumination gives superior performance in the selection of color weak individuals.

Recommendations:

From the experience gained in the experiment which has been described, the following recommendations are made:

1. Nine plates in the second edition should be eliminated or improved in the interests of diagnostic value and ease of administration.

2. If the present number of plates in the second edition is retained, the standard for normal color perception should be that no more than ten plates are misinterpreted.

3. Recording of the responses to each plate should be required for record purposes.

4. Each plate should be numbered in the index.

5. Page edges should be either "tabbed" or in-cut so that any plate or group of plates can be found readily without the possibility of error.

6. Access to any test for color perception used by the U. S. Navy should be restricted to Army and Navy Medical Officers. Otherwise, the possibility that individuals may have memorized any official test will probably restrict its value for the Navy.